NASA
Technical
Paper
2802

February 1988

Influence of Base Modifications on In-Flight Base Drag in the Presence of Jet Exhaust for Mach Numbers From 0.7 to 1.5

Sheryll Goecke Powers

NASA

NASA
Technical
Paper
2802

1988

Influence of Base Modifications on In-Flight Base Drag in the Presence of Jet Exhaust for Mach Numbers From 0.7 to 1.5

Sheryll Goecke Powers

Ames Research Center
Dryden Flight Research Facility
Edwards, California

National Aeronautics
and Space Administration

Scientific and Technical
Information Division

CONTENTS

ABSTRACT

The use of external modifications in the base region to reduce the base drag of a blunt-base body in the presence of jet engine exhaust was investigated in flight. Base pressure data were obtained for the following configurations: (1) blunt base; (2) blunt base modified with splitter plate; and (3) blunt base modified with two variations of a vented cavity. Reynolds number based on the length of the aircraft ranged from 1.2×10^8 to 3.1×10^8. Mach number M ranges were $0.71 \leq M \leq 0.95$ and $1.10 \leq M \leq 1.51$. The data were analyzed using the blunt base for a reference, or baseline, condition.

For $1.10 \leq M \leq 1.51$, the reduction in base drag coefficient provided by the vented cavity configuration ranged from 0.07 to 0.05. These increments in base drag coefficient at $M = 1.31$ and 1.51 result in base drag reductions of 27 and 24 percent, respectively, when compared to the blunt base drag. For $M < 1$, the drag increment between the blunt base and the modifications is not significant.

INTRODUCTION

The flight requirements of many aircraft can compromise smooth aerodynamic lines in the base region. These compromises can result in a base region with high drag, such as a blunt base, as for example, the blunt base caused by propulsion requirements or the blunt base caused by the stability requirements of hypersonic vehicles. It is usually desirable, if possible, to reduce the in-flight base drag of an aircraft.

Two- and three-dimensional experimental studies have shown that interfering with the vortex formation caused by the wake of a blunt body may reduce the base drag component due to vortex shedding (Bearman, 1965; Goodyer, 1966; Hoerner, 1965; Mair, 1965; Nash and others, 1966; Powers and others, 1986; Roshko, 1954; Saltzman and Hintz, 1967). In these cases, the vortex formation was influenced by adding external modifications to the base. For example, incompressible, low Reynolds number, wind-tunnel studies by Roshko (1954) and Bearman (1965) have shown that the effects of vortex formation and hence the base drag of a two-dimensional configuration could be reduced by placing a splitter plate in the wake (a flat plate placed normal to the base surface so as to form a reattachment surface for the impinging separated flow). Both the eddy shedding frequency and the location of the vortices were affected by the splitter plate. A quasi-two-dimensional flight study (Saltzman and Hintz, 1967) successfully demonstrated the effectiveness of the splitter plate in reducing base drag for Reynolds numbers near 10^7 and Mach numbers to 0.90. Another configuration successful in reducing base drag is a cavity. The two-dimensional wind-tunnel study of Nash and others (1966) showed that a cavity at the trailing edge of a blunt base shape could also affect the vortex formation. The base drag, for Nash and others (1966), was reduced for subsonic Mach numbers but not for supersonic Mach numbers.

These two-dimensional studies, and the three-dimensional studies of Goodyer (1966), Mair (1965), and Powers and others (1986), demonstrated that external modifications in the base region can sometimes be effective in reducing the drag of blunt base bodies. For these studies, the surface and base pressures of the bodies were not influenced by a jet engine exhaust. However, the base regions of airplanes are often adjacent to, ahead of, or behind the jet engine exhaust.

For instance, the blunt base fuselage closure of the F-111 airplane is located between and behind the airplane's two jet engines. Because the effects of jet exhaust on the adjacent surfaces are difficult to predict, aft fuselage configurations similar to the F-111 configuration were the subject of several wind-tunnel investigations (for example, Re and others, 1967; Runckel, 1966; Wilmoth and others, 1968). The flow interference effects about the aft fuselage of the F-111 aircraft were also investigated in the in-flight study of Taillon (1974).

The fuselage closure of the F-111 airplane provided an opportunity to study the in-flight base drag reducing effectiveness of external modifications to a blunt base body in the presence of engine exhaust. Base pressure data on the fuselage closure were obtained for the blunt base of the aircraft, and for base modifications consisting of a splitter plate and a vented cavity, respectively. Mach number M ranges were $0.71 \leq M \leq 0.95$ and $1.10 \leq M \leq 1.51$.

NOMENCLATURE

A	area of blunt base, 2.55 ft^2
A_v	area of slots for vented cavity, ft^2
C_{D_b}	base drag coefficient
C_{p_b}	base pressure coefficient
h	base width, in
l	length of splitter plate, in
M	free-stream Mach number
p	free-stream static pressure, lb/ft^2
p_b	base pressure, lb/ft^2
p_{T_7}	turbine discharge total pressure, lb/ft^2
W_l	maximum width for lower portion of blunt base, in
W_m	minimum width at waist of blunt base, in
W_u	maximum width for upper portion of blunt base, in
ΔC_{D_b}	difference between C_{D_b} of blunt base and modified base

DESCRIPTION OF EXPERIMENT

The blunt base fuselage closure of the F-111 aircraft is located between the two engines (fig. 1). The peanut-shaped fuselage closure, the base, and the location of the base with respect to the engines is more easily seen in figure 2. The distance between the centerlines of the two engines, at the engine exit plane, is 60 in. The engine exit plane is approximately 18 in forward of the base plane of the fuselage closure. The two engines are Pratt and Whitney (West Palm Beach, Florida) TF30-P-3 axial flow, dual compressor turbofans. Further details about the aircraft and the propulsion system may be obtained from Cooper and others (1977) and Painter and Caw (1979).

The three base shapes investigated—the blunt base, the blunt base with a splitter plate, and the blunt base with a vented cavity—are shown in figure 3. All joints and openings on the body surface and in the base region were carefully sealed for each of the configurations to ensure that air did not leak from inside the fuselage. The blunt base (figs. 2 and 3(a)), as indicated by the name, provided an abrupt (nearly a right angle) change in the surface contour. The dimensions for the base are shown in figure 4. The area A of the base (the area covered by the fuel dump is included) is 2.55 ft^2. The fuel dump for the aircraft is near the bottom of the fuselage closure (see figs. 2, 3(a) or 3(e) for an end view; fig. 3(c) for side view). The nominal dimensions for the fuel dump are listed in table 1.

TABLE 1.—NOMINAL DIMENSIONS FOR FUEL DUMP

Dimension	Value, in
Length	12.0
Maximum width (ahead of exit)	
Top-to-bottom	9.5
Side-to-side	6.0
Fuel dump exit diameter	7.0

Two different splitter plate configurations (both had the same nominal dimensions) were tested. Originally, the only splitter plate configuration to be tested was the aluminum splitter plate; however, the 0.06-in-thick aluminum plate was severely buffeted during its only flight. The aluminum plate was not damaged during the flight, but the support rods broke loose and scored the plate. The 0.13-in steel splitter plate, which replaced the aluminum splitter plate, did not have a buffet problem. Both splitter plates (figs. 3(b) and (c)) had a gap of 0.5 in between the blunt base and the splitter plate. In other words, neither splitter plate was flush with the surface. The vertical dimension for the splitter plates was 25.0 in and the longitudinal dimension was 14.0 in. The effective splitter plate length for each configuration is 14.5 in (sum of the gap width and the longitudinal dimension). Thus, the ratio of the effective splitter plate length (14.5 in) to maximum base width (14.4 in) is 1.0. The significance of this ratio on base pressure coefficient was demonstrated by Nash and others (1966). Curves from Nash and others (1966) are shown in figure 5. The splitter plate dimensions used for the present study were derived from wind-tunnel data (Nash and others, 1966) and structural considerations of the present experiment.

The vented cavity modification is shown in figures 3(d) and 3(e). The sides of the vented cavity were fastened to the outside of the fuselage closure and in general continued the lines of the fuselage closure. The joint between the vented cavity and fuselage closure was carefully sealed to prevent air leaks. The depth of the cavity, distance from the base face to the trailing edge of the cavity, is 12.3 in. There are 11 slots on each side (22 slots total), and the length of each slot is 9.8 in. Two vented cavity configurations were used for the study. The difference between the configurations was the slot width. The V-shaped area at the top (fig. 3(e)) remained the same for both configurations. The slot width was 0.63 in for one configuration and 0.76 in for the other configuration. These two slot widths resulted in ratios of slot area (including the V-shaped area) to blunt base area, A_v/A, of 0.40 and 0.47, respectively. The significance of this ratio on base pressure coefficient was demonstrated by Nash (1965). The curve from Nash (1965) is shown in figure 6. The cavity and slot dimensions were derived from wind-tunnel data and information contained in Nash (1965) and from structural considerations of the present experiment.

The locations of the seven pressure orifices are shown in figure 4. These locations were used for all the configurations. The orifices were manifolded (fig. 3(a)); therefore, only one pressure was measured. Two differential pressure transducers (one sensitive and one with a larger pressure range) were used in measuring the pressure. The differential pressure transducers were referenced to a plenum pressure. The plenum pressure source was a static orifice on the upper wing surface near the fuselage. The plenum pressure was measured by a high-resolution, absolute pressure transducer. Air data quantities, such as free-stream impact and static pressures, were obtained from high-resolution pressure transducers connected to the aircraft's nose boom ports. The temperature environment was controlled for each of the transducers to verify that these transducers remained within the temperature limits of their calibration during flight.

All the data obtained for the flight study were recorded on magnetic tape using a pulse code modulation (PCM) system. All records were synchronized by a time code generator.

TEST PROCEDURES

Data were obtained for 1 min for each test point, beginning after the airplane achieved steady-state flight conditions (that is, flight conditions for which the altitude and airspeed of the airplane were essentially constant). Several samples were chosen from each 1-min time period, and these samples were averaged and then analyzed. The same nominal flight conditions were repeated for each configuration to help minimize any effects on base pressure that could be caused by changes in engine afterburner conditions, engine exhaust nozzle area, or in blow-in door positions. The supersonic data for the vented cavity with $A_v/A = 0.47$ were limited to a maximum Mach number of approximately 1.2 because other experiments on the airplane imposed Mach number limitations for those flights. Data were obtained for at least two separate flights for each configuration except the aluminum splitter plate, which was flown for only one flight.

TEST CONDITIONS

Data were obtained for dynamic pressures of approximately 500 lb/ft^2 throughout the Mach number range. Some data were also obtained at additional dynamic pressures. The same nominal Mach numbers of 0.71, 0.80, 0.90, 0.95, 1.10, 1.31, and 1.51 and their respective dynamic pressures were obtained for each configuration. Aircraft, or free-stream, angle-of-attack values ranged from 3.4° to 6.6° for the majority of the data. An exception to this were a few angles of attack up to 8° for the vented cavity with $A_v/A = 0.47$. Aircraft, or free-stream, sideslip angles were between ±0.5°, except for a few that were near −1.0°. The rudder was in the zero, or null, position for all the tests. The aircraft was long enough that incidental changes in transition location would not affect the data; therefore, the turbulent flow Reynolds number was based on the aircraft body length of 72 ft and ranged from 1.2×10^8 to 3.1×10^8.

BASE DRAG COEFFICIENT ANALYSIS

The base drag coefficient C_{D_b} for each configuration is calculated from the following equation

$$C_{D_b} = -C_{p_b} = -(p_b - p)/.7\mathrm{M}^2\mathrm{p}$$

where

C_{p_b}	is base pressure coefficient,
p	free-stream static pressure, and
M	free-stream Mach number.

Because the base pressure is measured from a seven-orifice manifold, the base drag coefficient is an average value for the base.

Increments between the base drag coefficients of the blunt base and the modifications were used to evaluate the effectiveness of the different configurations. The standard deviation for the increments in the base drag coefficient is estimated to be ± 0.007. Considerations used in obtaining this value for the standard deviation are (1) the repeatability of the data, (2) the steady-state flight conditions maintained during the test points, (3) the fact that average data were obtained from each test point, and (4) the free-stream static pressure and the free-stream Mach number were obtained from a calibrated nose boom.

RESULTS AND DISCUSSION

Averaged data are presented in this section for each configuration. The data for the blunt base is the baseline, or reference, condition. The possible effects of angle of attack or Reynolds number on the base drag coefficient at a given Mach number were investigated for each of the base configurations, but no apparent relationship was detected. The lack of a relationship was not unexpected because turbulent flow begins far upstream of the base region, and turbulent flow is relatively insensitive to the modest excursions in angle of attack and Reynolds number experienced during this study. Also, the base drag coefficient, at a given Mach number, was not found to be a function of either the different wing sweeps or the different dynamic pressures.

Before presenting base drag coefficients, the engine operating conditions for the different configurations are compared. Because the same nominal Mach numbers and altitudes were repeated for each configuration, the engine afterburner conditions, engine exhaust area, and blow-in door positions are approximately the same for each configuration. The engine parameter used to compare the repeatability of the engine conditions is the average of the ratio of turbine discharge total pressure to free-stream pressure, p_{T_7}/p. In figure 7, p_{T_7}/p is shown as a function of Mach number for all the configurations. In general, the agreement between the average values for the blunt base and the modifications is good. One exception is the vented cavity with $A_v/A = 0.47$ for $M > 0.9$. Except for these data, these comparisons provide assurance that, at a given Mach number, any differences observed between the base drag coefficients for the blunt base and the modifications are caused by the modification and these differences are not significantly influenced by propulsion factors.

The average base drag coefficients for each of the configurations are compared as a function of Mach number in figure 8. The negative base drag coefficients observed for $M < 1$ mean, of course, that the base surface actually is providing some thrust instead of adding to the total aircraft drag. The negative base drag coefficients, while not typical, have been observed for other base drag coefficients in the presence of jet exhaust (Saltzman and others, 1968) and were also observed for the F-111 fuselage closure study of Taillon (1974). The drag differences between the configurations are small in this Mach number region.

The crossover Mach number, the Mach number where the base pressure coefficient is zero, is approximately 1.1 for the blunt base and the splitter plate, and closer to 1.2 for both vented cavities. The base drag increases as Mach number increases from 1.10 to 1.51. However, the vented cavities have less base drag than either the blunt base or the splitter plate.

The increment of base drag coefficient between the blunt base and the various modifications is shown as a function of Mach number in figure 9. For $M < 1$, the increment between the blunt base and the various modifications is near zero for much of the data, with the splitter plate (square symbols) having marginally less drag than the blunt base. The maximum increment observed in this Mach number region is approximately 0.01. However, the estimated standard deviation, as stated in the previous section, is ± 0.007 for $0.71 \leq M \leq 1.51$. Thus, the increment between the blunt base and the various modifications is not considered significant.

For $M > 1$, the vented cavity with $A_v/A = 0.40$ (diamond symbols) has significant reductions in base drag coefficient. The reductions range from 0.05 to

0.07. The 0.02 reduction in base drag coefficient for the splitter plate at 1.51 is offset by the small increases (less than −0.01) at 1.10 and 1.31 Mach numbers. The increments for the vented cavity with $A_v/A = 0.47$ are not shown because of possible effects of p_{T_7}/p on base drag coefficient. For M > 1, this configuration had p_{T_7}/p values significantly different from the other configurations.

To relate these increments to base drag reduction, assume a flight condition having a free-stream dynamic pressure of 500 lb/ft^2. For this dynamic pressure, altitude varies from 31,400 to 44,300 ft as Mach number increases from 1.10 to 1.51. Then, for the 2.55-ft^2 base area of this study, each 0.01 increment in base drag coefficient means a 12.75-lb reduction in base drag. The base drag reductions obtained for the vented cavity with $A_v/A = 0.40$ for each test supersonic Mach number are presented in table 2.

TABLE 2.—BASE DRAG REDUCTIONS

Mach number	Increment, ΔC_{D_b}	Base drag reduction, lb
1.10	0.07	89
1.31	0.05	64
1.51	0.06	76

The increments in base drag coefficient at Mach numbers of 1.31 and 1.51 result in base drag reductions of 27 and 24 percent, respectively, when compared to the blunt base drag. Because the base drag coefficient for the blunt base is near zero for the 1.10 Mach number data, the percentage change is not calculated.

These reductions in base drag are translated to a change in total aircraft drag for the 1.51 Mach number data. A 500 lb/ft^2 dynamic pressure is again assumed (corresponds to an altitude of 44,300 ft). Then for an angle of attack of 5.4°, a drag coefficient of 0.049 was obtained from Cooper and others (1977). Using the F-111 TACT wing area of 604 ft^2, the 76-lb base drag reduction resulted in 0.5 percent reduction in total aircraft drag or a 0.5 percent increase in range.

CONCLUSIONS

The use of external modifications in the base region to reduce the base drag of a blunt base body in the presence of jet engine exhaust was investigated in flight. Base pressure data were obtained for the following configurations: blunt base, blunt base modified with splitter plate, and blunt base modified with two variations of a vented cavity. Reynolds number based on the length of the aircraft ranged from 1.2×10^8 to 3.1×10^8. Mach number M ranges were $0.71 \leq M \leq 0.95$ and $1.10 \leq M \leq 1.51$. The data were analyzed using the blunt base for a reference, or baseline, condition. The analysis led to the following conclusions:

1. For $1.10 \leq M \leq 1.51$, the reduction in base drag coefficient provided by the vented cavity base ranged from 0.07 to 0.05. Base drag reductions of 89, 64, and 76 lb were obtained for Mach numbers of 1.10, 1.31, and 1.51, respectively, for a dynamic pressure of 500 lb/ft^2. The increments in base drag coefficient at Mach numbers of 1.31 and 1.51 result in base drag reductions of 27 and 24 percent, respectively, when compared to the blunt base drag.

2. For M < 1, the base drag coefficients are negative (the base surface is actually providing some thrust) for all the configurations and become more negative as Mach number increases from 0.70 to 0.96. The crossover Mach number, the Mach number where the base drag coefficient is zero, is approximately 1.1 for the blunt base and the splitter plate base and closer to 1.2 for both vented cavities. The base drag becomes significantly positive as Mach number increases from 1.10 to 1.51.

3. For M < 1, the increment between the blunt base and the various modifications is not significant.

Ames Research Center
Dryden Flight Research Facility
National Aeronautics and Space Administration
Edwards, California, June 18, 1987.

REFERENCES

Bearman, P.W.: *Investigation of the Flow Behind a Two-Dimensional Model With a Blunt Trailing Edge and Fitted With Splitter Plates.* J. Fluid Mech., vol. 21, part 2, Feb. 1965, pp. 241–256.

Cooper, James M., Jr.; Hughes Donald L.; and Rawlings, Kenneth, III: *Transonic Aircraft Technology-Flight-Derived Lift and Drag Characteristics, Volume I of II.* Air Force Flight Test Center, Edwards Air Force Base, AFFTC-TR-77-12, 1977.

Goodyer, M.J.: *Some Experimental Investigations Into the Drag Effects of Modifications to the Blunt Base of a Body of Revolution.* Institute of Sound and Vibration Research, Southhampton University, England, report no. 150, July 1966.

Hoerner, Sighard F.: *Fluid-Dynamic Drag.* Published by the author (148 Busteed Drive, Midland Park, New Jersey), 1965.

Mair, W.A.: *The Effect of a Rear-Mounted Disc on the Drag of a Blunt-Based Body of Revolution.* Aeronaut. Quart., vol. 16, Nov. 1965, pp. 350–360.

Nash, J.F.: *A Discussion of Two-Dimensional Turbulent Base Flows.* National Physical Laboratory, United Kingdom, NPL Aero report 1162, 1965.

Nash, J.F.; Quincey, V.G.; and Callinan, J.: *Experiments on Two-Dimensional Base Flow at Subsonic and Transonic Speeds.* Ministry of Aviation of United Kingdom, Aeronautical Research Council, Reports and Memoranda no. 3427, 1966.

Painter, Weneth D.; and Caw, Lawrence J.: *Design and Physical Characteristics of the Transonic Aircraft Technology (TACT) Research Aircraft.* NASA TM-56048, 1979.

Powers, Sheryll Goecke; Huffman, Jarrett K.; and Fox, Charles H., Jr.: *Flight and Wind-Tunnel Measurements Showing Base Drag Reduction Provided by a Trailing Disk for High Reynolds Number Turbulent Flow for Subsonic and Transonic Mach Numbers.* NASA TP-2638, 1986.

Re, Richard J.; Wilmoth, Richard G.; and Runckel, Jack F.: *Investigation of Effects of Afterbody Closure and Jet Interference on the Drag of a Twin-Engine Tactical Fighter.* NASA X-1382, 1967.

Roshko, Anatol: *On the Drag and Shedding Frequency of Two-Dimensional Bluff Bodies.* NACA TN-3169, 1954.

Runckel, Jack F.: *Jet-Exit and Airframe Interference Studies on Twin-Engine-Fuselage Aircraft Installations.* NASA TM X-1274, 1966.

Saltzman, Edwin J.; Goecke, Sheryll A.; and Pembo, Chris: *Base Pressure Measurements on the XB-70 Airplane at Mach Numbers From 0.4 to 3.0.* NASA TM X-1612, 1968.

Saltzman, Edwin J.; and Hintz, John: *Flight Evaluation of Splitter-Plate Effectiveness in Reducing Base Drag at Mach Numbers From 0.65 to 0.90.* NASA TM X-1376, 1967.

Taillon, Norman V.: *Flight-Test Investigation of the Aerodynamic Characteristics and Flow Interference Effects About the Aft Fuselage of the F-111A Airplane.* NASA TN D-7563, 1974.

Wilmoth, Richard G.; Norton, Harry T., Jr.; and Corson, Blake W., Jr.: *Effect of Engine-Interfairing Modifications on the Performance of a Powered Twin-Jet Fighter-Airplane Model at Mach 1.20.* NASA TM X-1534, 1968.

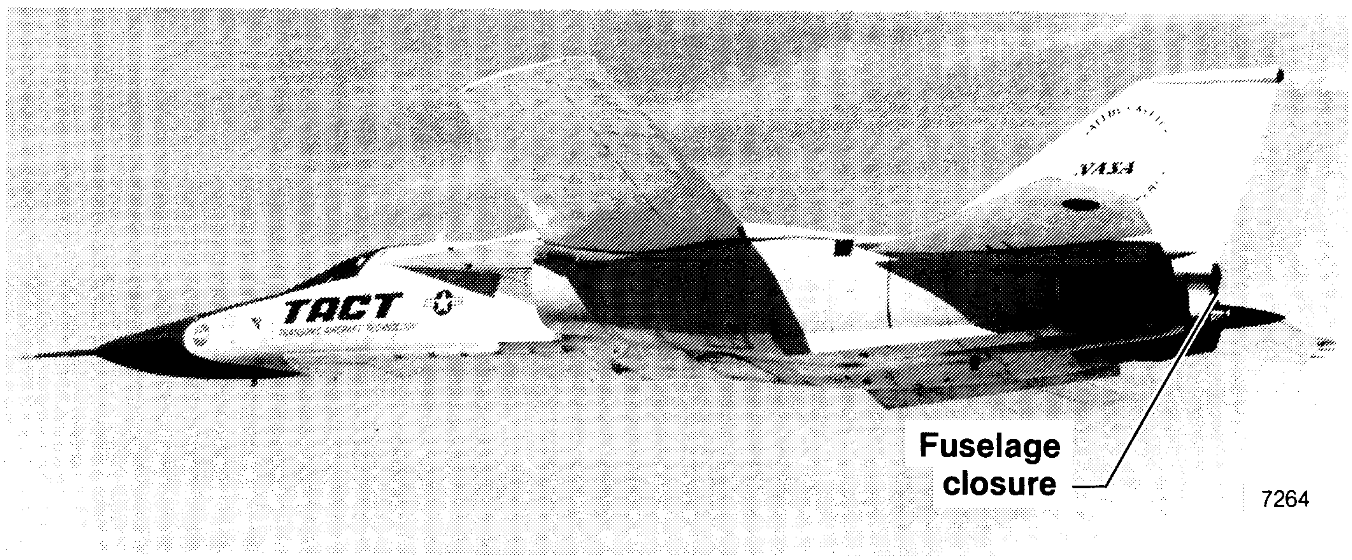


Figure 1. In-flight photograph of the F-111 TACT aircraft.

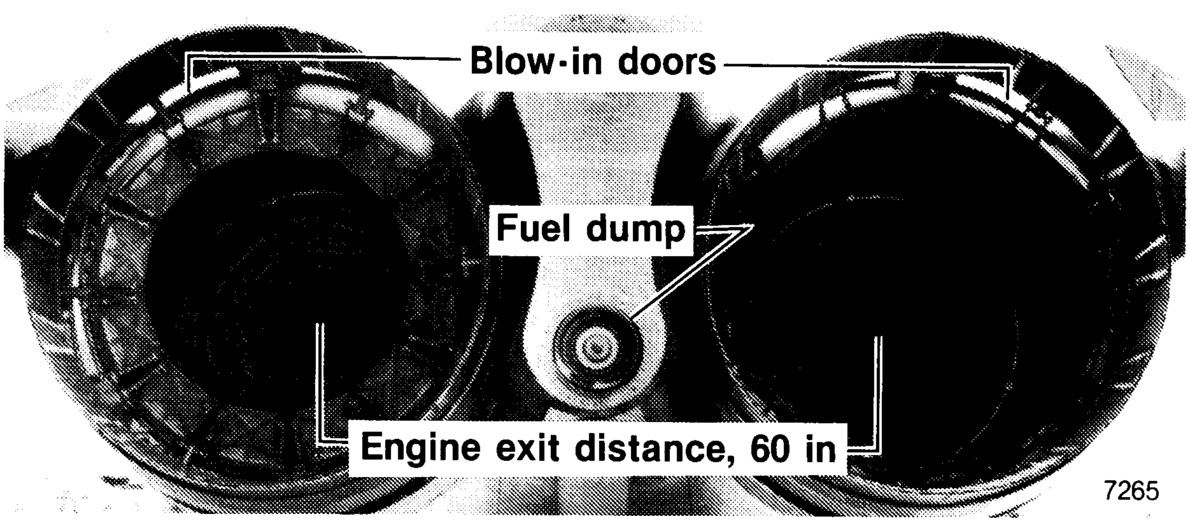
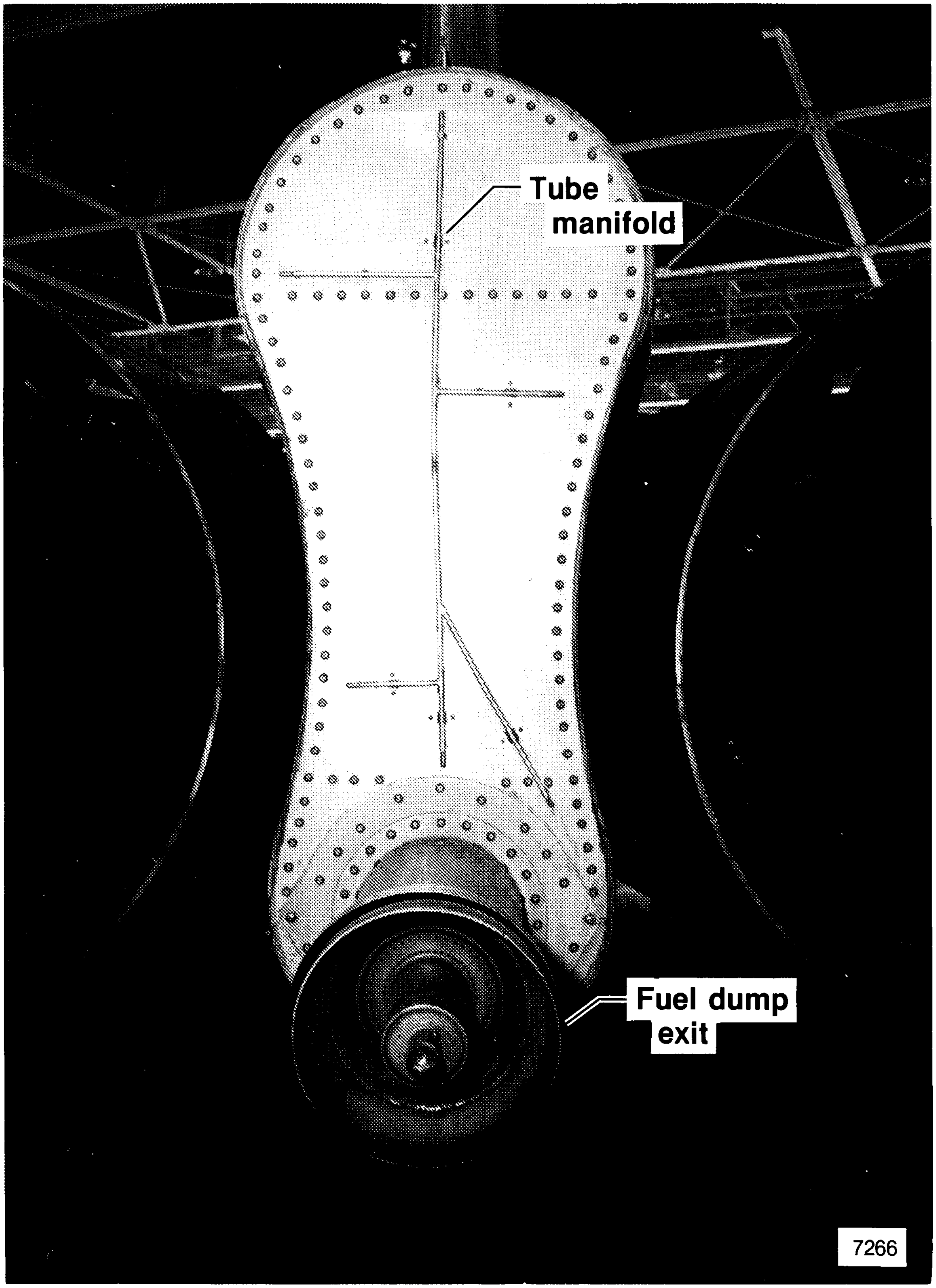
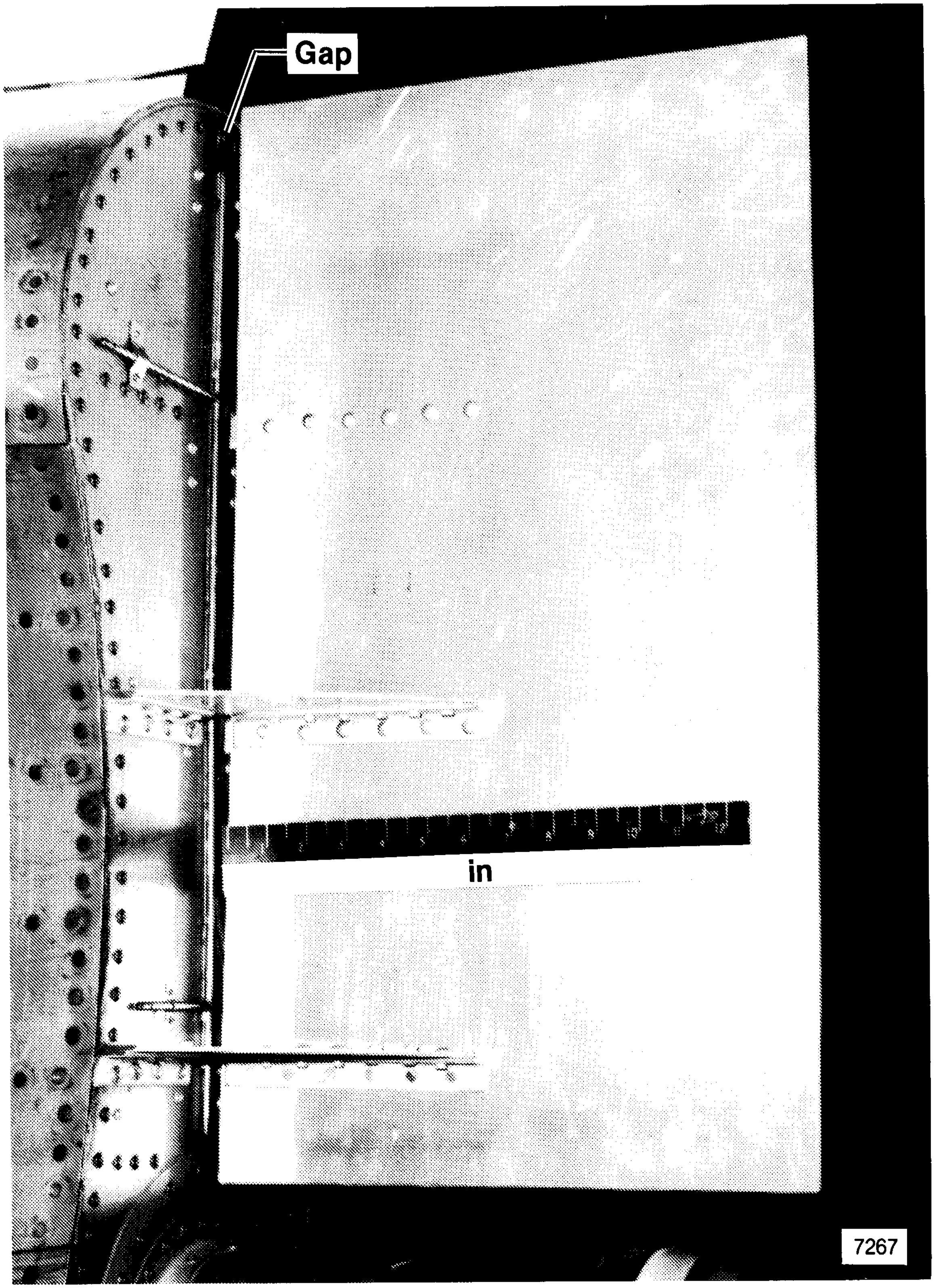


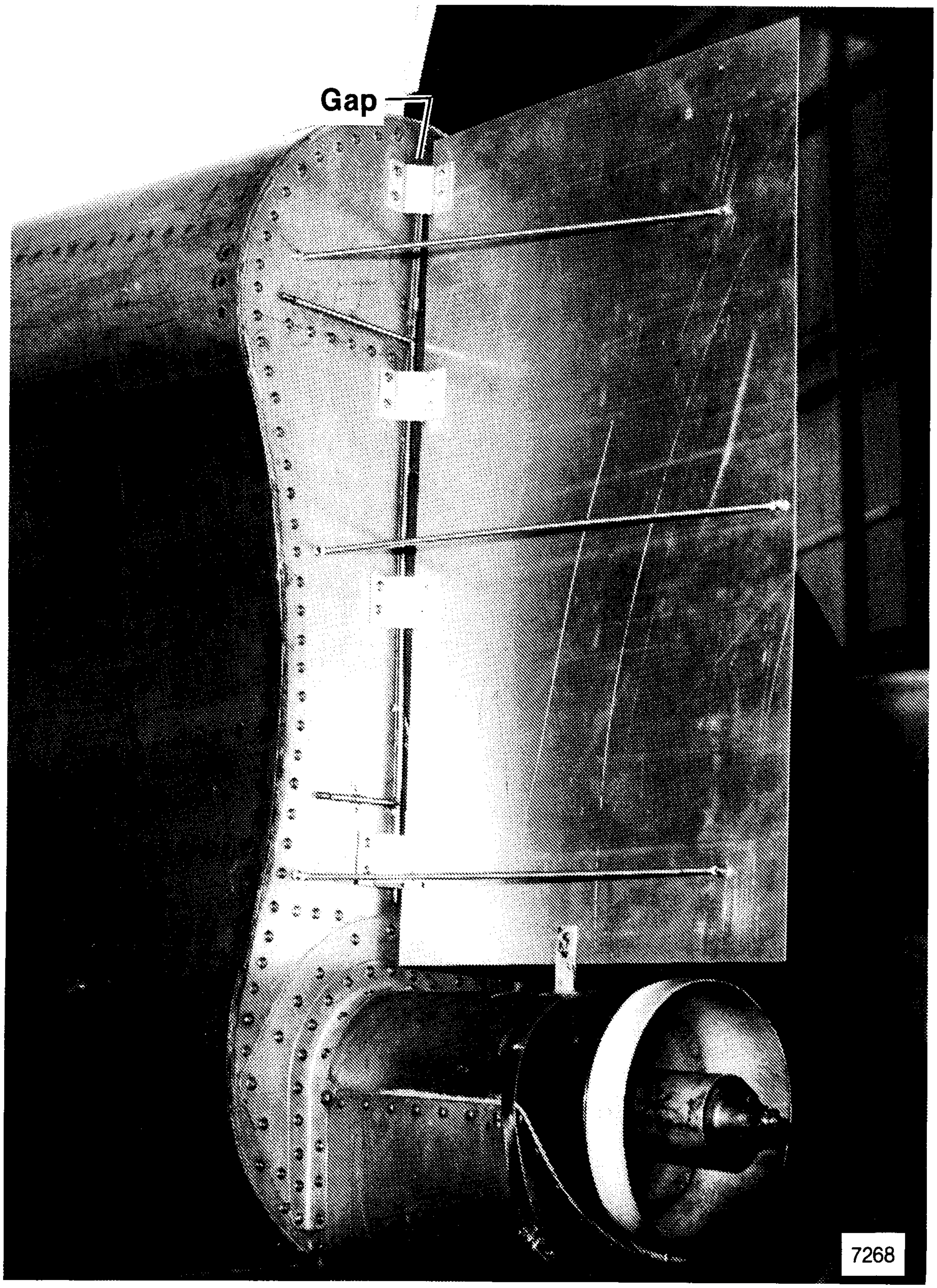
Figure 2. Rear-view photograph of the F-111 aircraft. Nozzles are fully open.



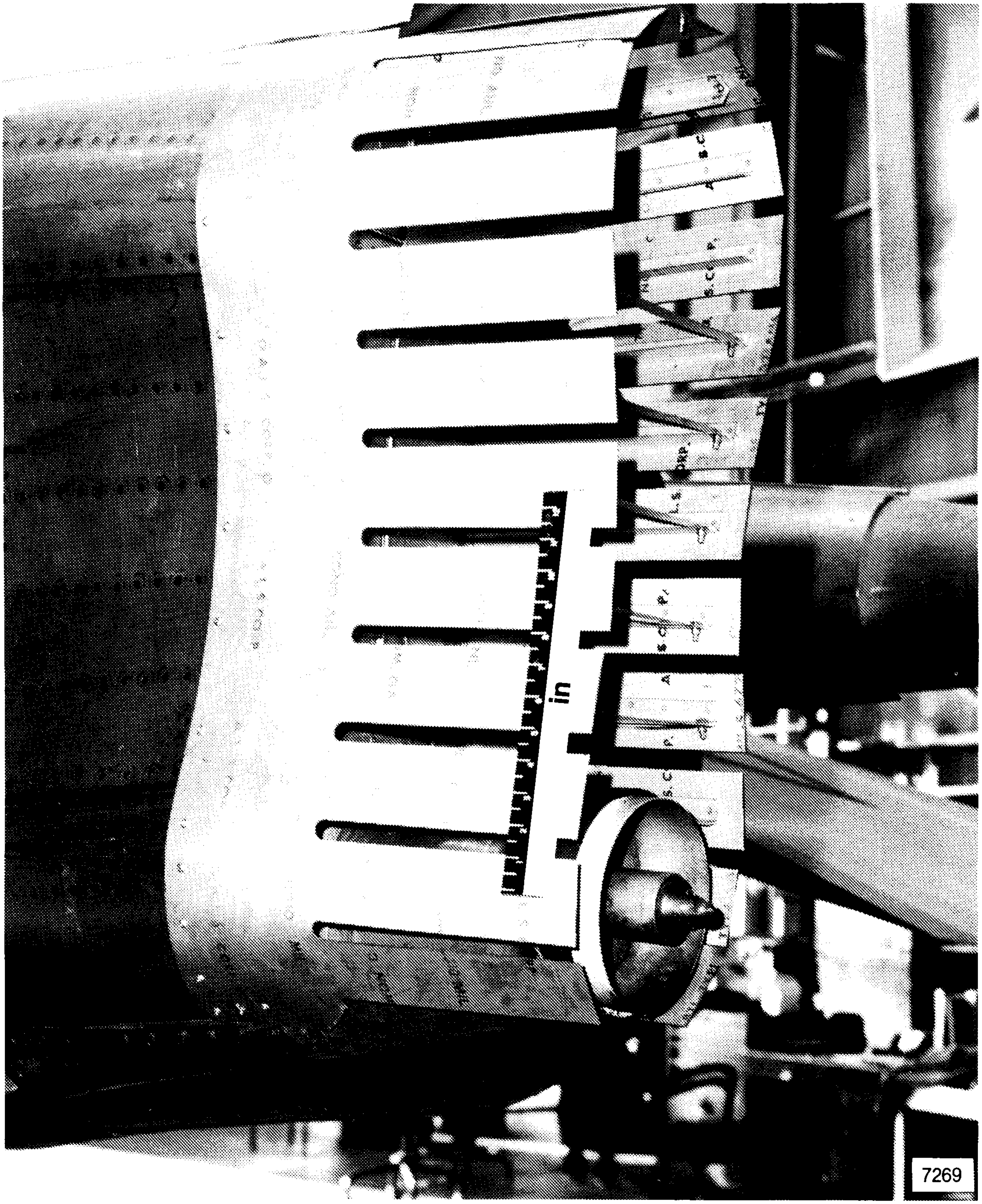
(a) Blunt base. Orifices are in the tube manifold.
Figure 3. Photographs of tested base configurations.



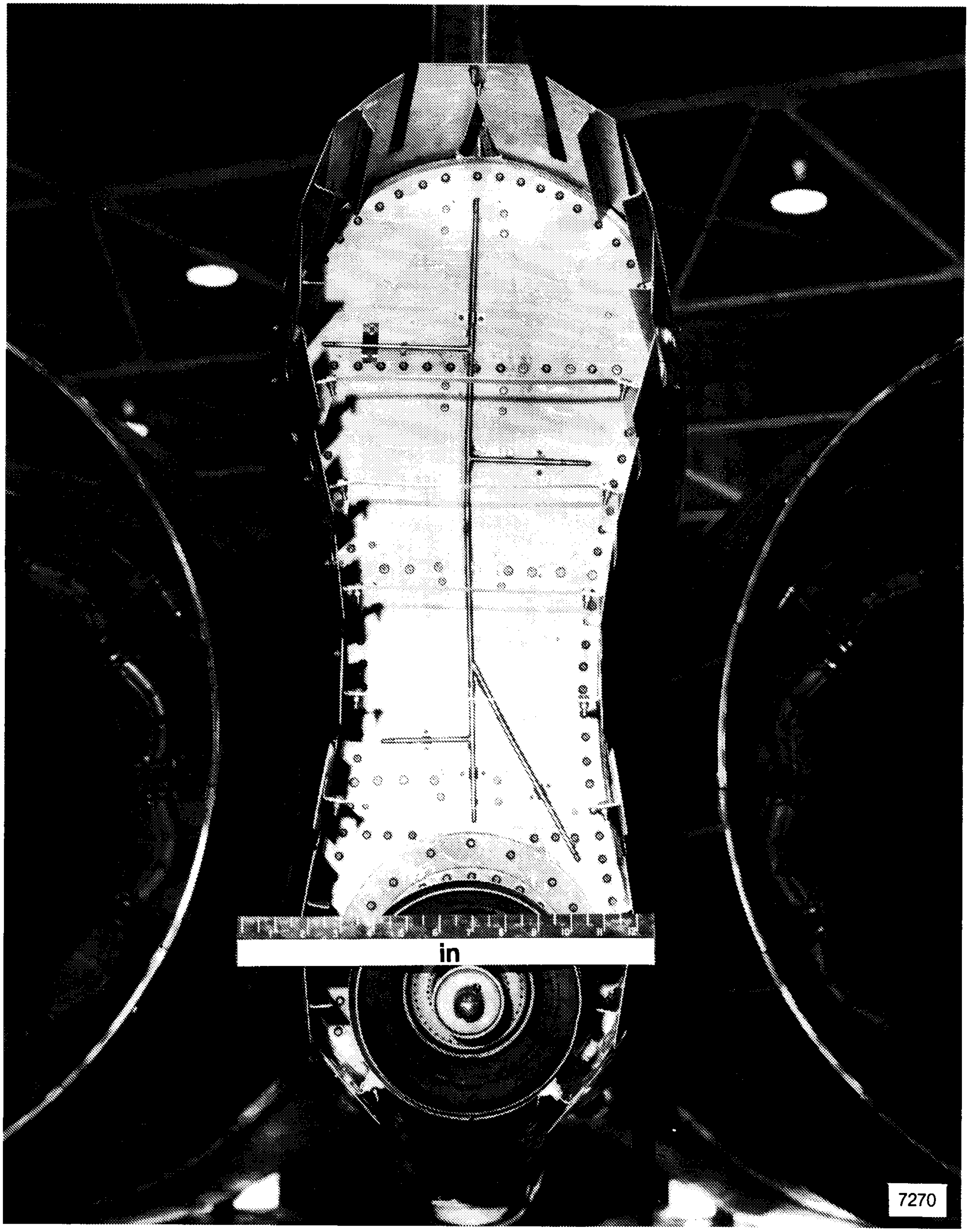
(b) Side-view of blunt base with steel splitter plate.
Figure 3. Continued.



(c) Side-view of blunt base with aluminum splitter plate.
Figure 3. Continued.



(d) Side-view of blunt base with vented cavity.
Figure 3. Continued.



(e) Blunt base with vented cavity, viewed from rear.
Figure 3. Concluded.

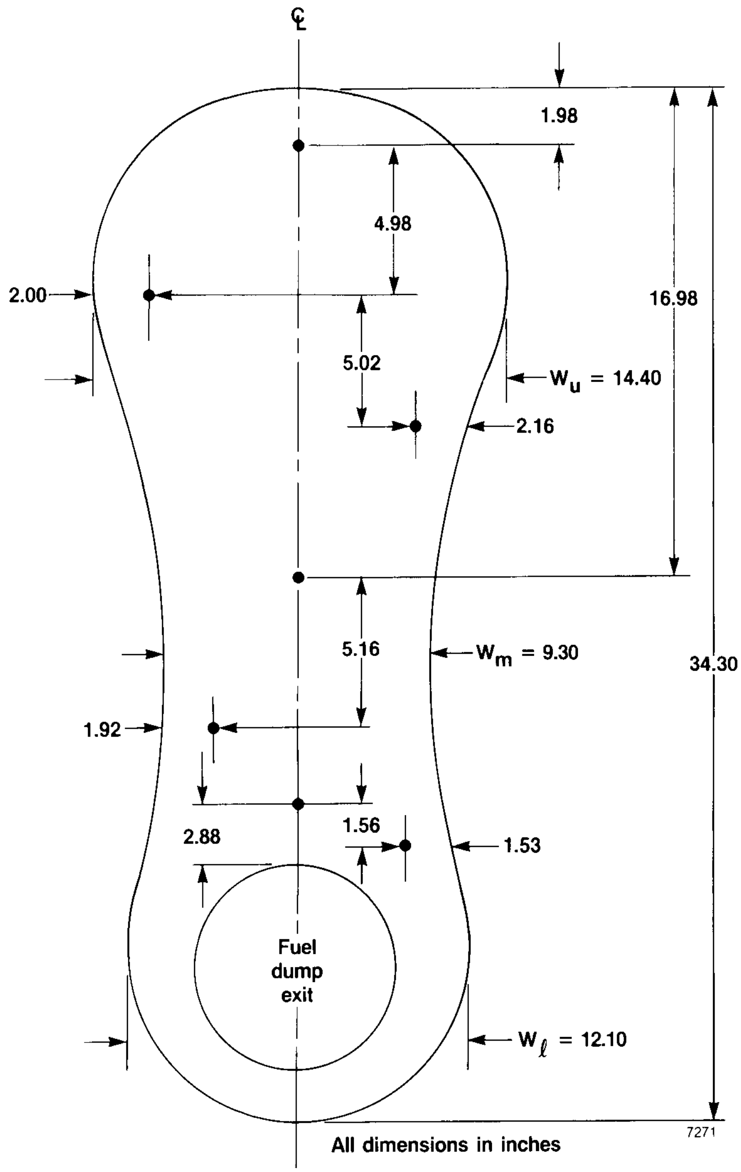


Figure 4. Sketch showing size of base and locations of the orifices • on base. Orifices are in tube manifold. See figure 3(a). Distances are given to orifice center.

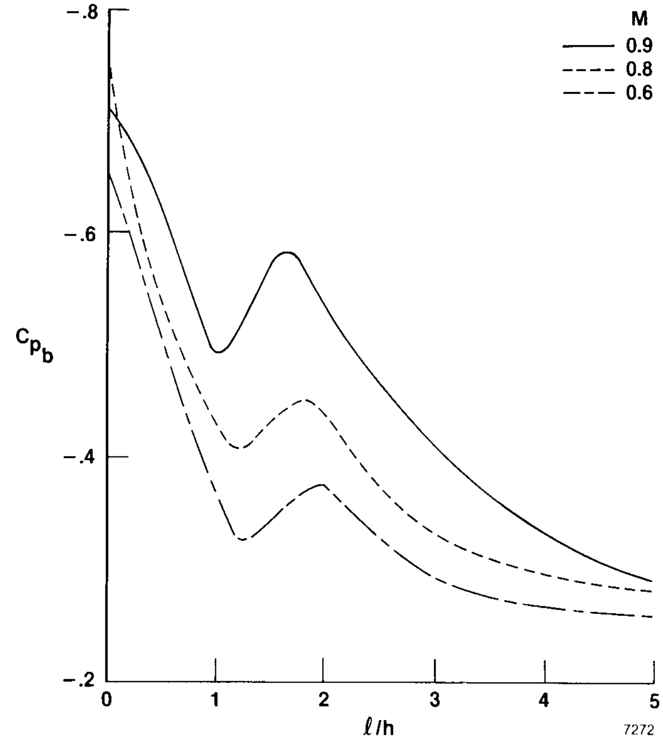


Figure 5. Variation of base pressure coefficient with splitter plate length. Curves from Nash and others, 1966.

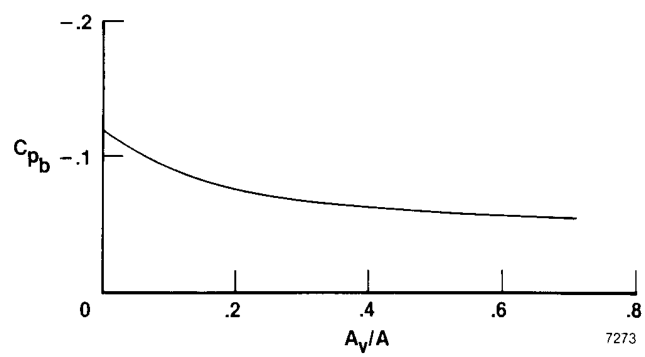


Figure 6. Variation of base pressure coefficient with slot area for Mach number 3.1. Curve from Nash, 1965.

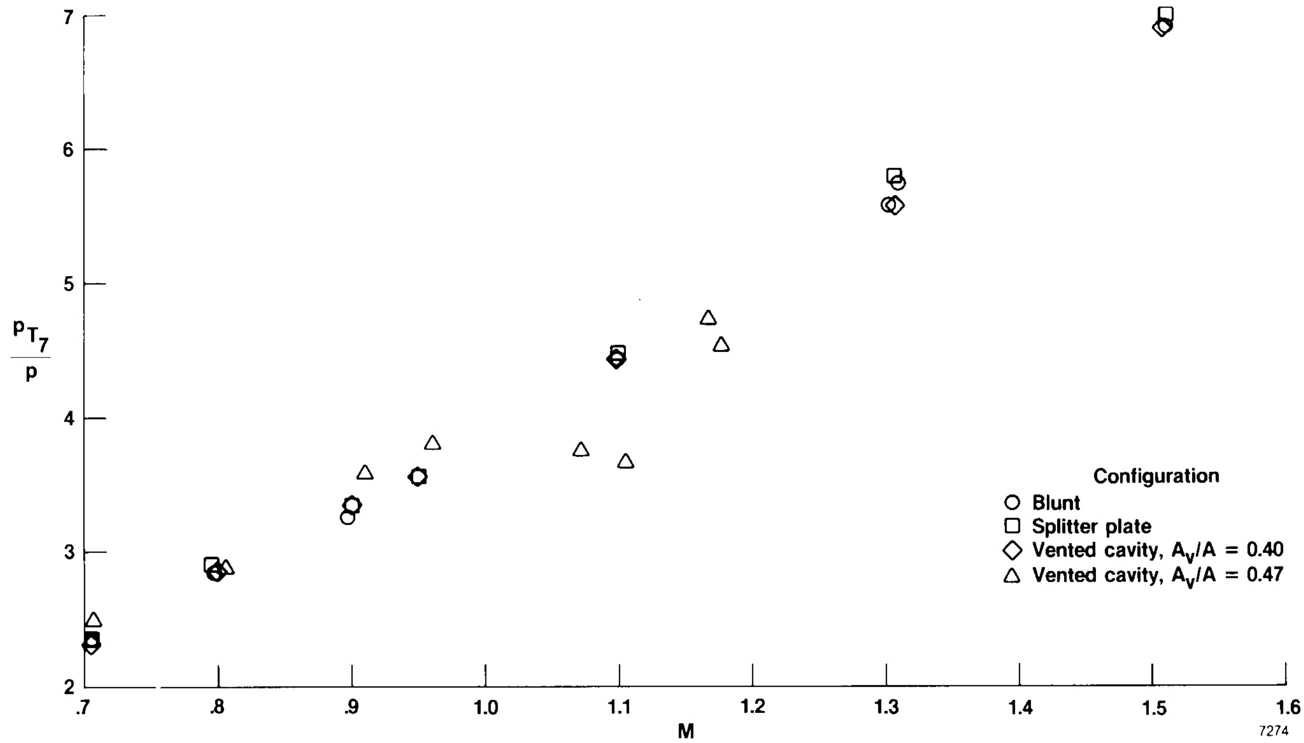


Figure 7. Comparison of average ratio of turbine discharge total pressure to free-stream pressure for the different configurations.

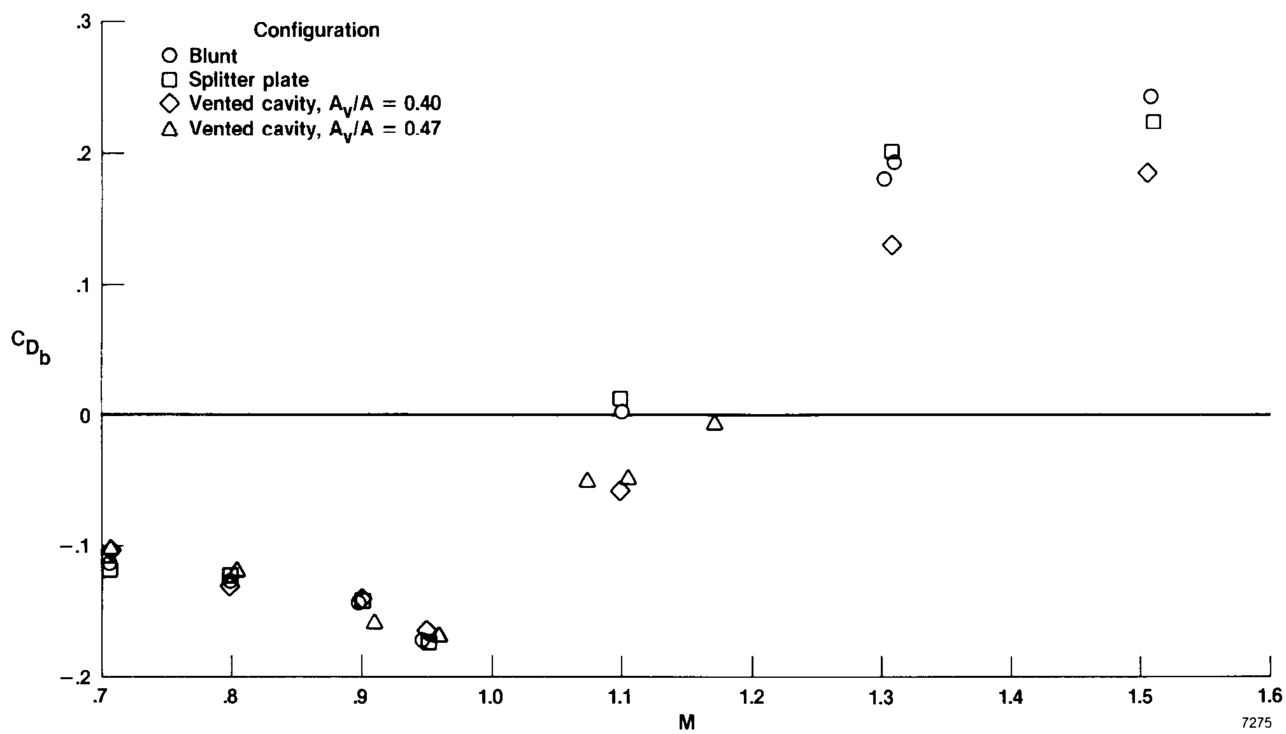


Figure 8. Comparison of average base drag coefficients for the different configuration.

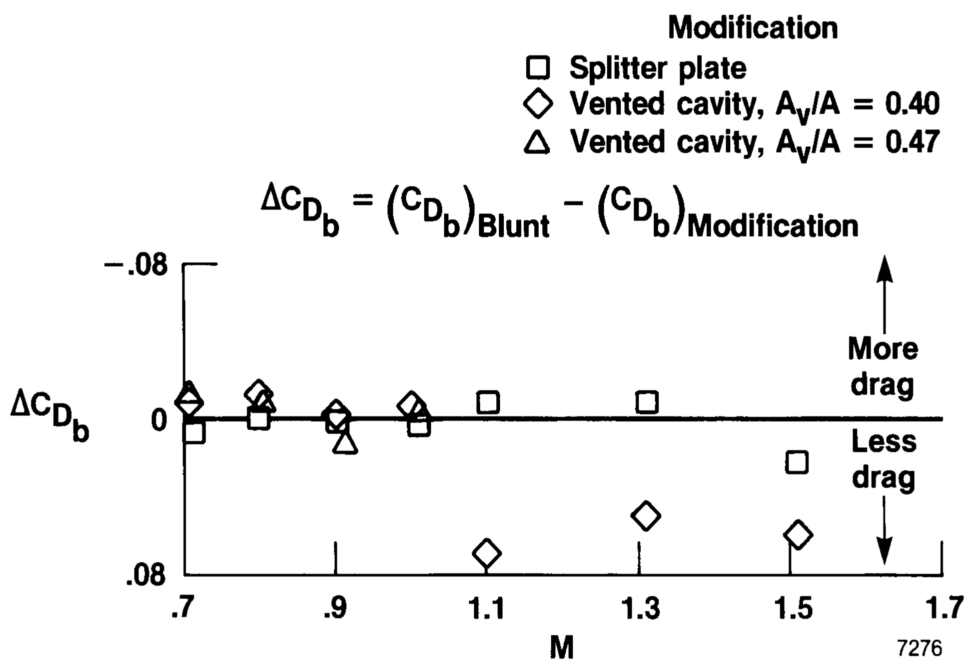


Figure 9. Increment between base drag coefficient of blunt base and modifications.

1. Report No. NASA TP-2802	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle Influence of Base Modifications on In-Flight Base Drag in the Presence of Jet Exhaust for Mach Numbers From 0.7 to 1.5		5. Report Date February 1988
		6. Performing Organization Code
7. Author(s) Sheryll Goecke Powers		8. Performing Organization Report No. H-1408
9. Performing Organization Name and Address NASA Ames Research Center Dryden Flight Research Facility P.O. Box 273, Edwards, CA 93523-5000		10. Work Unit No. RTOP 533-02-11
		11. Contract or Grant No.
12. Sponsoring Agency Name and Address National Aeronautics and Space Administration Washington, DC 20546		13. Type of Report and Period Covered Technical Paper
		14. Sponsoring Agency Code

15. Supplementary Notes

16. Abstract

The use of external modifications in the base region to reduce the base drag of a blunt-base body in the presence of jet engine exhaust was investigated in flight. Base pressure data were obtained for the following configurations: (1) blunt base; (2) blunt base modified with splitter plate; and (3) blunt base modified with two variations of a vented cavity. Reynolds number based on the length of the aircraft ranged from 1.2×10^8 to 3.1×10^8. Mach number M ranges were $0.71 \leq M \leq 0.95$ and $1.10 \leq M \leq 1.51$. The data were analyzed using the blunt base for a reference, or baseline, condition. For $1.10 \leq M \leq 1.51$, the reduction in base drag coefficient provided by the vented cavity configuration ranged from 0.07 to 0.05. These increments in base drag coefficient at $M = 1.31$ and 1.51 result in base drag reductions of 27 and 24 percent, respectively, when compared to the blunt base drag. For $M < 1$, the drag increment between the blunt base and the modifications is not significant.

17. Key Words (Suggested by Author(s)) Base drag reduction, Blunt bodies, Turbulent flow	18. Distribution Statement Unclassified — Unlimited. Subject category 34

19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of Pages 18	22. Price* A02

***For sale by the National Technical Information Service, Springfield, Virginia 22161.**

NASA-Langley, 1988